Claims:

1. An energy recovery system, for extracting electrical energy from a source of heat, the system having a circulating working fluid, comprising:

a first heat exchanger for receiving source fluid, incorporating at least part of the heat of the source of heat and for receiving said working fluid, whereby heat is transferred from the source fluid to the working fluid;

an expansion unit, arranged to receive the working fluid output from the first heat exchanger whereby mechanical energy is imparted to the expansion unit;

an electromechanical conversion unit, coupled to the expansion unit, for converting said mechanical energy into electrical energy,

a cooling system, coupled to the expansion unit and to the first heat exchanger, for receiving the working fluid from the expansion unit, cooling the fluid, and supplying the fluid to the first heat exchanger.

2. The system of claim 1, wherein:

the system is a closed system with a circulating working fluid,

the first heat exchanger is adapted for receiving source fluid, incorporating the heat, at a first temperature and outputting said waste fluid at a second temperature, and for receiving said working fluid at a third temperature and outputting the working fluid at a fourth temperature, said fourth temperature being higher than said third temperature and higher than the boiling point of the working fluid;

the expansion unit comprises a turbine unit, arranged to receive the working fluid output from the first heat exchanger at a first pressure and to output the working fluid at a second pressure, said second pressure being lower than the first pressure, the turbine unit thereby imparting rotational energy to a turbine shaft mounted within the turbine unit; and

the electromechanical conversion unit is coupled to the turbine shaft, for converting said rotational energy into electrical energy.

3. The system of claim 2, wherein the cooling system includes a second heat exchanger, coupled to the turbine unit and to the first heat exchanger, for receiving a first supply of working fluid from the turbine unit at said fifth temperature and outputting working fluid from said first supply at a sixth temperature, said sixth temperature being lower than said fifth temperature;

wherein the second heat exchanger is further adapted to receive a second supply of working fluid in liquid form at a seventh temperature and output working fluid from the second supply of fluid to said first heat exchanger at said third temperature.

4. The system of claim 3, wherein the cooling system further includes a condensing unit, coupled to the second heat exchanger and adapted to receive a supply of cooling fluid, for receiving the working fluid output by the second heat exchanger at said sixth temperature and outputting working

fluid in liquid form at said seventh temperature, said seventh temperature being lower than said sixth temperature and lower than the boiling point of the working fluid.

5. The system of claim 4, wherein the cooling system includes a pump, coupled to the cooling unit, for receiving the liquid working fluid at said seventh temperature and pumping said liquid working fluid to said second heat exchanger, thereby providing said second supply of working fluid to the second heat exchanger.

6. The system of any of claims 1 to 5, wherein said first temperature is about 110 to about 225°C.

7. The system of any of claims 1 to 6, wherein said second temperature is about 80 to about 140°C.

8. The system of any of claims 1 to 7, wherein said first temperature is about 180°C and said second temperature is about 123 °C.

9. The system of any of the preceding claims, wherein said first pressure is about 10 to 30 bar absolute.

10. The system of any of the preceding claims, wherein said second pressure is about 0.5 to 2 bar absolute.

11. The system of any of the preceding claims, wherein the turbine shaft is mounted on a bearing within said turbine unit, and said working fluid permeates said turbine unit, thereby providing lubrication of said bearing.

12. The system of any of the preceding claims, wherein the working fluid comprises a single component fluid selected from the alkanes.

13. The system of any of the preceding claims, wherein the working fluid comprises a fluid with a boiling point of about 30-110°.

14. The system of any of the preceding claims, wherein the electromechanical conversion unit includes an alternator adapted to output electric current.

15. The system of any of the preceding claims, wherein the electromechanical conversion unit includes an electrical conditioning unit, coupled to said alternator, for altering the frequency of the current received from the alternator and outputting current at mains frequency.

16. The system of any of the preceding claims, wherein the expansion unit comprises a turbine unit having a shaft and at least one turbine stage mounted thereon, the or each turbine stage incorporating a set of vanes.

17. The system claim 16, wherein the at least one turbine stage is made of aluminium or steel.

18. The system claim 16, wherein the at least one turbine stage is made of plastics material.

19. The system claim 18, wherein the plastics material is (a) polyetheretherketone (PEEK) containing carbon fibre, for example PEEK with 40% carbon fibre, (b) Ultern 2400, or (c) Valox 865.

20. An energy recovery system substantially as hereinbefore described with reference to the accompanying drawings.

21. The use of HFE-7100 or hexane or water as the working fluid and/or lubrication fluid in the energy conversion system of any of the preceding claims.

22. The use of one of the alkanes as the working fluid and/or lubrication fluid in the energy conversion system of any of the appended claims.

23. An electrical energy generation system, comprising:

a microturbine system, the microturbine system comprising

a combustion unit, coupled to a source of fuel, for combusting said fuel and outputting a first exhaust fluid,

a turbine, coupled for receiving said first exhaust fluid whereby rotational energy is imparted, in use, to a turbine shaft of the turbine, the turbine being adapted to a output second exhaust fluid,

an intermediate heat transfer unit, coupled for receiving said second exhaust fluid and adapted for performing a transfer of heat from the second exhaust fluid to an intermediate heat transfer fluid and to output the intermediate heat transfer fluid after said transfer of heat, and

an energy recovery system according to any of claims 1 to 20, the energy conversion system having said first heat exchanger coupled for receiving said intermediate heat transfer fluid, the intermediate heat transfer fluid embodying said source of heat.

24. The electrical energy generation system of claim 23, wherein the microturbine system further includes a compressor, coupled to the turbine and the combustion unit, and driven, in use, by the turbine shaft, the compressor receiving a supply of oxygen-containing fluid and supplying said oxygen-containing fluid in a compressed state, in use, to the combustion unit.

25. The electrical energy generation system of claim 23 or 24, wherein the microturbine system further includes a generator, coupled to the turbine and driven, in use, by the turbine shaft, the generator being adapted to output electrical energy.

26. The electrical energy generation system of any of claims 23 to 25, further including a recuperator, disposed between the turbine and the intermediate heat transfer unit and coupled for receiving said second exhaust fluid and outputting third exhaust fluid to the intermediate heat transfer unit, the recuperator being further adapted for receiving a supply of oxygen-containing fluid, for example from the compressor, and for conveying said oxygen-containing fluid to the combustor after transfer of heat thereto from said second exhaust fluid.

27. The electrical energy generation system of claim 26, the recuperator comprises a heat exchanger.

28. An electrical energy generation system, comprising:

an internal combustion system, the internal combustion system comprising

an internal combustion engine, coupled to a source of fuel, for combusting said fuel and outputting an engine exhaust fluid, the internal combustion engine being arranged whereby rotational energy is imparted, in use, to an drive shaft,

an intermediate heat transfer unit, coupled for receiving said engine exhaust fluid and adapted for performing a transfer of heat from the engine exhaust fluid to an intermediate heat transfer fluid and to output the intermediate heat transfer fluid after said transfer of heat, and

an energy recovery system according to any of claims 1 to 20, the energy conversion system having said first heat exchanger coupled for receiving said intermediate heat transfer fluid, the intermediate heat transfer fluid embodying said source of heat.

29. The electrical energy generation system of claim 28, wherein the internal combustion system further includes a generator, coupled to the internal combustion engine and driven, in use, by the drive shaft, the generator being adapted to output electrical energy.

30. The electrical energy generation system of claim 28 or 29, wherein the internal combustion engine is coupled to a supply of fuel and to a supply of oxygen-containing fluid.

31. An electrical energy generation system, comprising:

a waste gas disposal stack, the waste gas disposal stack including

a base stage, the base stage including a blower for blowing oxygen-containing gas into the waste gas disposal stack,

a combustion stage, adjacent the base stage, coupled to a source of waste gas, the waste gas being or including a combustible gas, the combustion stage being adapted to combust, in use, said waste gas in said oxygen-containing gas,

a mixer stage, adjacent said combustion stage, adapted to generate a mixture of gases comprising air mixed with the combustor exhaust gases resulting from said combustion stage,

an intermediate heat transfer unit, coupled for receiving said mixture of gases and adapted for performing a transfer of heat from the mixture of gases to an intermediate heat transfer fluid and to output the intermediate heat transfer fluid after said transfer of heat, and

an energy recovery system according to any of claims 1 to 20, the energy conversion system having said first heat exchanger coupled for receiving said intermediate heat transfer fluid, the intermediate heat transfer fluid embodying said source of heat.

32. The electrical energy generation system of claim 31, wherein the blower comprises an electrically-powered blower, the blower is electrically coupled to the electromechanical conversion unit, and at least part of the electrical energy generated, in use, by the energy conversion system powers the blower.

33. The electrical energy generation system of any of claims 23 to 32, wherein the intermediate heat transfer unit comprises a heat exchanger, and/or intermediate heat transfer fluid comprises heat transfer oil.

34. A radial inflow turbine unit, comprising:

a housing with an inlet port for receiving fluid at a first pressure;

a shaft mounted on a bearing within the housing and having an axis of rotation;

a turbine, disposed on the shaft, the turbine comprising

a first turbine stage, comprising a first series of vanes mounted on the shaft, said fluid received by the inlet port being radially incident on said first series of vanes and exiting the first turbine stage at a third pressure and in a first predetermined direction,

a second turbine stage, comprising a second series of vanes mounted on the shaft,

a conduit for conveying the fluid exiting the first turbine stage to the second turbine stage,

said fluid received by the second turbine stage being radially incident on said second series of vanes and exiting the second turbine stage at a second pressure and in a second predetermined direction,

wherein said fluid imparts rotational energy to said shaft at both said first and second turbine stages.

35. The turbine unit of claim 34, wherein the first pressure is higher than the third pressure, and the third pressure is higher than the second pressure.

36. The turbine unit of claim 34 or 35, wherein the first pressure is about 2 to 10 times the second pressure.

37. The turbine unit of any of claims 34 to 35, wherein the third pressure is about 3-4 times the second pressure.

38. The turbine unit of any of claims 34 to 37, wherein the radial dimension of said second turbine stage is greater than the radial dimension of the first turbine stage.

39. The turbine unit of claim 38, wherein the radial dimension of second turbine stage is about 1.25 times the radial dimension of the first turbine stage.

40. The turbine unit of any of claims 34 to 39, wherein the axial dimension of said first turbine stage is about 0.3 to 0.375 times the radial dimension of the first turbine stage.

41. The turbine unit of any of claims 34 to 40, wherein the axial dimension of said second turbine stage is about 0.35 to 0.4 times the radial dimension of the second turbine stage.

42. The turbine unit of any of claims 34 to 41, further including:

a third turbine stage, comprising a third series of vanes mounted on the shaft,

a conduit for conveying the fluid exiting the second turbine stage to the third turbine stage, said fluid received by the third turbine stage being radially incident on said third series of vanes and exiting the third turbine stage at a fourth pressure and in a third predetermined direction,

wherein said fluid imparts rotational energy to said shaft at said first, second and third turbine stages.

43. The turbine unit of claim 42, wherein the axial dimension of said third turbine stage is about 1/3 times the radial dimension of the third turbine stage.

44. The turbine unit of any of claims 34 to 43, wherein said first, second and/or third predetermined directions is generally axial.

45. The turbine unit of any of claims 34 to 44, wherein said fluid is a gas.

46. The turbine unit of any of claims 34 to 45, wherein said fluid is HFE-7100 or hexane or water.

47. The turbine unit of any of claims 34 to 45, wherein said fluid is one of the alkanes.

48. The turbine unit of any of claims 34 to 47, wherein said fluid permeates the housing, thereby providing lubrication of the bearing.

49. The turbine unit substantially as hereinbefore described with reference to the accompanying drawings.

50. A waste energy recovery system, for extracting energy from a source of waste heat, the system being a closed system with a circulating working fluid, comprising a heat exchanger, an electromechanical conversion unit, a cooling system and a turbine unit according to any of claims 34 to 49, the heat exchanger supplying, in use, the working fluid to said turbine unit.

51. A bearing for supporting a shaft rotatable about an axis and at least partially disposed within a housing, comprising:

a bearing member, fixedly attached to the housing and having a first bearing surface, opposite a second bearing surface on the shaft, said first and second bearing surfaces extending generally transverse to the axis, and a cylindrical internal channel defining a third bearing surface extending generally parallel to the axis and disposed opposite a fourth bearing surface on the shaft,

the bearing member including conduits adapted to convey lubricating fluid into at least the space third and fourth bearing surfaces.

52. The bearing of claim 51, wherein the bearing member has a generally T-shaped cross-section.

53. The bearing of claim 51 or 52, wherein the bearing member has, on the end thereof opposite the first bearing surface, a fifth bearing surface extending generally transverse to the axis.

54. The bearing of claim 52, wherein the first surface on the bearing element is defined by a raised annular surface on the top of the 'T' extending partially between the inner radial limit and the outer radial limit of the bearing member.

55. The bearing of claim 53, wherein a plurality of elongate first recesses are provided extending radially in the first surface, thereby facilitating flow of lubricant fluid to the space opposite the first surface.

56. The bearing of claim 55, wherein the first recesses extend partially between the inner radial limit and the outer radial limit of the first surface.

57. The bearing of any of claims 53 to 56, wherein a plurality of elongate second recesses are provided extending radially in the fifth surface, thereby facilitating flow of lubricant fluid to the space opposite the fourth surface.

58. The bearing of claim 57, wherein the second recesses extend partially between the inner radial limit and the outer radial limit of the fifth surface.

59. The bearing of any of claims 52 to 58, wherein at a point between the opposite ends of the elongate part of the 'T'-shaped bearing member, a circumferential recess is defined in the surface at the outer radial limit of the bearing member.

60. The bearing of claim 59, wherein a plurality of first lubrication channels are provided, extending radially between the circumferential recess and the inner radial limit of the bearing member, thereby permitting flow of lubricant fluid between the exterior of the bearing member and the internal cylindrical channel.

61. The bearing of any of the claims 58 to 60, wherein the bearing member includes a plurality of second lubrication channels, each channel extending axially between a first elongate recess on the first surface and a respective opposite second elongate recess on the fifth surface.

62. The bearing of any of claims 51 to 61, wherein the number of first and/or second elongate recesses is between 2 and 8, and preferably 6.

63. The bearing of any of claims 51 to 62, wherein the number of second lubrication channels is between 2 and 8.

64. The bearing of any of claims 51 to 63, further including a washer, wherein, in use, one surface of the washer abuts the fifth surface of the bearing member and the other surface of the washer is adapted to abut a corresponding surface of a drive element, for example a turbine.

65. The bearing substantially as hereinbefore described with reference to the accompanying drawings.

66. A energy recovery system, for extracting energy from a source of waste heat, the system being a closed system with a circulating working fluid, comprising a heat exchanger, an electromechanical conversion unit, a cooling system and a turbine unit, the heat exchanger supplying, in use, the working fluid to said turbine unit as a gas, wherein the turbine unit is mechanically coupled to the electromechanical conversion unit via a shaft, the shaft being supported by a bearing according to any of claims 51 to 65.

67. The system of claim 66, further including a secondary working fluid supply line from the cooling system to the bearing whereby working fluid is supplied to the exterior of the bearing member, thereby providing the lubricant fluid for said bearing.

68. The system of claim 67, wherein the working fluid is supplied to the bearing as a liquid.

69. A rotary magnetic coupling, comprising:

a first rotary member, including a first shaft having disposed thereon a first magnetic member, said first shaft, in use, being driven by a source of rotational energy,

a second rotary member, including a second shaft having disposed thereon a second magnetic member, said second rotary member, in use, receiving rotational energy from the first rotary member through coupling of the first and second magnet members,

wherein one of said first and second magnetic members, or both, comprise a plurality of magnet sections disposed at different angular positions with respect to the axis of said first and second shafts.

70. The magnetic coupling of claim 69, wherein the first rotary member is disposed within a hermetically sealed housing, a portion of the housing being disposed between the first rotary member and the second rotary member and being made of a non-magnetic material.

71. The magnetic coupling of claim 70, wherein the non-magnetic material comprises stainless steel, nimonic alloy, or plastic.

72. The magnetic coupling of claim 69 or 70, wherein the first magnetic member comprises an inner generally cylindrical armature portion integral with the first shaft and a plurality of first magnet sections fixedly attached on the exterior of the armature portion.

73. The magnetic coupling of any of claims 69 to 72, wherein the second magnetic member comprises an outer generally cylindrical supporting portion integral with the second shaft and a plurality of second magnetic sections fixedly attached to the interior of the supporting portion.

74. The magnetic coupling of any of claims 69 to 73, wherein the first magnetic member further comprises a containment shell, disposed on the exterior of the first magnet sections, for retaining said first magnet sections in position during high-speed rotation of the first shaft.

75. The magnetic coupling of any of claims 73 to 74, wherein the containment shell is made of a composite material, for example CFRF, Kevlar or GRP.

76. The magnetic coupling of any of claims 70 to 75, wherein the first magnetic member is disposed inside the second magnetic member and separated therefrom by the portion of the housing.

77. The magnetic coupling of any of claims 69 to 76, wherein the magnet sections comprise dipole magnets the N-S direction of each extending radially.

78. The magnetic coupling of any of claims 69 to 72, wherein the first magnetic member is generally disc-shaped and comprises a first mounting section having fixedly mounted within it the plurality of first magnet sections, the first magnet sections thereby forming a disc shape.

79. The magnetic coupling of claim 78, wherein the second magnetic member is generally disc-shaped and comprises a second mounting section having fixedly mounted within it the plurality of second magnet sections, the second magnet sections thereby forming a disc shape.

80. The magnetic coupling of any of claims 69 to 79, wherein the first and second magnet sections form sectors of a disc.

81. The magnetic coupling of any of claims 78 to 80, wherein the first and second magnet sections comprise dipole magnets with the N-S direction of each extending axially.

82. The magnetic coupling of any of claims 78 to 81, wherein said first disc-shaped magnetic member is disposed axially aligned adjacent the second disc-shaped magnetic member and separated therefrom by the portion of the housing.

83. The magnetic coupling of any of claims 69 to 82, wherein the number of magnetic sections of said first magnetic member, and/or said second magnetic member, is an even number of 2 or more.

84. The magnetic coupling of any of claims 69 to 83, wherein the number of magnetic sections of said first magnetic member, and/or said second magnetic member, is 4.

85. The magnetic coupling of any of claims 69 to 84, wherein the said magnet sections are made of ferrite material, samarium cobalt or neodymium iron boron.

86. The magnetic coupling substantially as hereinbefore described with reference to the accompanying drawings.

87. A waste energy recovery system, for extracting energy from a source of waste heat, the system being a closed system with a circulating working fluid, comprising a heat exchanger, an electromechanical conversion unit, a cooling system and a turbine unit, the turbine being hermetically sealed and being coupled to the electromechanical conversion unit by a magnetic coupling according to any of claims 69 to 86.

88. A method carried out in a an energy recovery system for extracting energy from a source of waste heat, the system being a closed system with a circulating working fluid, comprising a heat exchanger, an electromechanical conversion unit including an alternator, a cooling system, a turbine unit, and a control system coupled to the electromechanical conversion unit and adapted to vary the voltage derived from the alternator, comprising the steps of:

(a) increasing the voltage by one voltage step;
(b) measuring the output power of the alternator;
(c) if the output power measured in step (b) is less than or equal to the previous output power,

(i) decreasing the voltage by one voltage step

(ii) repeating the steps of

(1) decreasing the voltage by one voltage step

(2) measuring the output power of the alternator;

while the output power measured in step (c)(ii)(2) is more than the previously measured output power, and

if the output power measured in step (b) is more than the previous output power, repeating the steps of

(iii) increasing the voltage by one voltage step

(iv) measuring the output power of the alternator

while the output power measured in step (c)(iv) is more than the previously measured output power.

89. The method of claim 88, wherein each step of increasing the voltage by one voltage step is replaced by the step of decreasing the voltage by one voltage step, and vice versa.

90. The method of claim 88 or 89, wherein the voltage step is about 1% to 2.5 % of the mean voltage.

91. The method of claim 88, 89 or 90, wherein step (a) is performed about every second.

92. The method of any of claims 88 to 91, wherein the step of measuring the output power of the alternator comprises measuring an output voltage V derived from the output of the alternator, measuring the output current I derived from the output of the alternator, and computing output power = V*I.

93. The method of any of claims 88 to 91, wherein the step of measuring the output power of the alternator comprises measuring the output power with a separate power-measuring device.

94. The method of any of claims 88 to 93, further comprising converting the alternator voltage from a first frequency to a second frequency.

95. The method of claim 94, wherein the first frequency is higher than the second frequency, and the second frequency is about the frequency of the mains supply.

96. The method of claim 94 or 95, wherein said step of converting the voltage comprises:

rectifying the voltage output by the alternator using a rectification circuit thereby deriving a dc voltage, and

generating an ac voltage from said dc voltage using a power-conditioning unit.

97. The method of any of claims 88 to 96 further comprising storing the last-measured value of the output power.

98. The method of controlling an energy recovery system substantially as hereinbefore described with reference to the accompanying drawings.

99. A programmable control system when suitably programmed for carrying out the method of any of claims 88 to 98, the system including a processor, a memory, an interface coupled to the electromechanical conversion unit, and a user interface.

100. The control system of claim 99, including a frequency conversion device for altering the frequency of an a.c. voltage.

101. A working fluid purification system for an energy conversion system, the energy conversion system being a closed system with a circulating working fluid circulating in a path therethrough and including an expansion device, for example a turbine, comprising:

an expansion tank;

a diaphragm within the expansion tank, thereby defining a variable volume connected for receiving said working fluid; and

a control valve disposed between said path and the expansion tank, the control valve being adapted to control the flow of fluid to and/or from said variable volume;

wherein the control valve is connected via a conduit to a connection point in the path, said connection point being at the highest point of said path.

102. The system of claim 101, wherein the control valve is mounted at a higher point than said connection point.

103. The system of claim 101 or 102, wherein the expansion tank is mounted at a higher point than said control valve.

104. The system of any of the preceding claims, further including a controller, the controller being adapted to open and close said control valve.

105. The system of claim 104, wherein the controller is configured to perform a purification cycle, said purification cycle comprising opening the control valve for a first predetermined period and closing the control valve for a second predetermined period.

106. The system of claim 105, wherein the controller is configured to perform, in a startup sequence of predetermined duration after switch-on of the system, a plurality of said purification cycles.

107. The system of claim 106, wherein said plurality of purification cycles comprises about 3 to 5 purification cycles.

108. The system of claims 105 to 107, wherein the first predetermined period is about 1 minute and said second predetermined period is about ten minutes.

109. The system of any of claims 101 to 108, further including a pressure sensor coupled to the controller; wherein the controller is configured to perform at least one purification cycle when the pressure indicated by the sensor is above a predetermined level.

110. A working fluid purification system substantially as hereinbefore described with reference to the accompanying drawings.

111. An energy recovery system for extracting electrical energy from a source of heat, comprising: the working fluid purification system of any of claims 101 to 110, a turbine, a heat exchanger, an electromechanical conversion unit, and a cooling system, the heat exchanger supplying, in use, the working fluid to said turbine.